ELECTRICAL AND OPTICAL STUDIES OF NANOPARTICLES DISPERSED NEMATIC AND FERROELECTRIC LIQUID CRYSTAL MIXTURES

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By

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I. INTRODUCTION

1.1 OVERVIEW

Liquid crystal nanoparticles remain a key topic of study in modern soft condensed matter studies. This claim is undeniable when you consider the various publications that have analysed hundreds of studies. “When F. Scott Fitzgerald initially offered the idea, it was a novel one. P. Brochard and R. G. A concept first proposed by de Gennes in 1970 to alter the properties of liquid crystals by mixing them with sub-micrometer magnetic particles was resurrected by the advent of nanotechnology in the late 1990s.” Since then, several other nanomaterials have been investigated in conjunction with liquid crystals. “These include magnetic, ferroelectric, dielectric, semiconductor, metal, polymer, and carbon-based nano-dopants (nanotubes, fullerenes, etc).”

Research on liquid crystals has covered a wide variety of scientific disciplines (LC). F. von Baer, an Austrian botanist, discovered this. The research of liquid crystals was initiated by Reinitzer, who synthesised the first such compound, cholesteryl benzoate. Because of this breakthrough, he is now known as the "grandfather of liquid crystal research." Liquid crystal materials have unique properties and uses. In addition to their use in displays, these materials show promise for use in photonics.

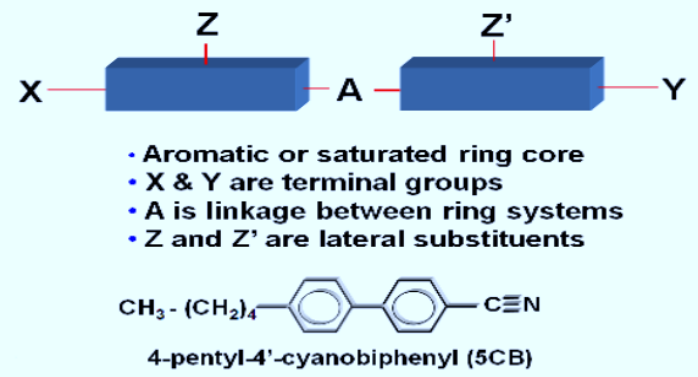

Figure 1: General Structure of Liquid crystals Molecule

“Watches, clocks, stereos, calculators, portable phones, personal organisers, notebooks, and laptop computers” are just some of the consumer and office electronics that have benefited from

the widespread use of liquid crystals in the production of electro-optical flat panel displays (FPDs) over the past 25 to 30 years.

1.2 NEMATIC LIQUID CRYSTALS

"The least ordered mesophase is the nematic one, in which the molecules only have orientational order. Anisotropic physical properties are made possible by the orientational arrangement of nematic LCs. Nematic LCs are the focus of extensive interdisciplinary study of super molecular systems. In recent years, there has been a surge of curiosity on the physicochemical effects of doping nematic LCs with ceramic nanoparticles.

Leonid O. Dolgov et al. investigated the electro-optical properties of nematic LC E7 that included two types of silica nanoparticles. The first nanoparticles, called aerosil, were created via the hydrolysis of chlorosilanes at high temperatures (A). The second kind of LC relied on monodisperse silica nanoparticles prepared by hydrolyzing tetraethylorthosilicate in alcohol and letting the resulting precipitate to develop in a controlled environment. Transmittance versus voltage curves for typical E7-A and E7-MNP suspensions are shown in Figures 1a and 1b, respectively. The samples were set up using their original transmittance T0 as a starting point. Saturation (Tsat) in transmittance was reached for both samples when the applied voltage was increased, as shown in Curve 1. Curve 2 depicts the transmission variation with decreasing voltage. As the voltage drops to zero, the system transitions to the state with residual transmittance (Tm)."

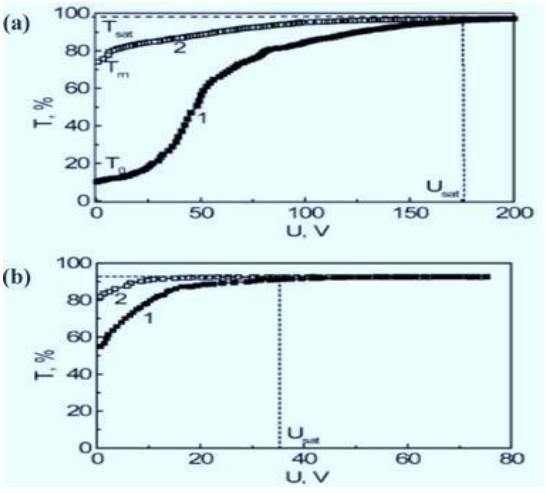

Figure 2: Transmittance versus curves for two types of suspensions voltage: (a) E7-A300 and (b) E7-SiO2 monodispersed nanoparticle.

The results shown that the structure and properties of nanoparticle-filled LCs are greatly impacted by the method of production. Colloidal solutions of chemically active mono scattered silica particles showed enhanced aggregation and even reactive merging when mixed with LCs. For LC-mono dispersed nanoparticle (MNP) composites to be useful, the solid phase must be kept in a highly dispersed state. These results were found to be useful in developing innovative composites using the wide variety of fillers made available by modern nanotechnologies.

1.3 FERROELECTRIC NANOPARTICLES

"As a rule, a little amount of nanomaterial is combined with the liquid crystal host to form ferroelectric nanoparticle-doped liquid crystals. Before creating the liquid crystal nano-dispersion, nanoparticles may either be in the form of Nano-powders or functionalized with the surfactant. In the former scenario, they are typically dispersed in an isotropic and non-ionic liquid carrier, such heptane or toluene (without any capping agent). To prevent nanoparticles from clumping together, a surfactant is necessary. By far, oleic acid is the most widely used surfactant today. However, this surfactant is not optimal due to the low affinity of its molecules for the surface of nanoparticles.

Nanoparticles are first disseminated in liquid crystals to prevent them from aggregating and to enable the non-ionic liquid containing the particles to entirely evaporate from the liquid crystal mixture. Sonication and/or extended shaking is then applied to the resultant dispersion. Making ferroelectric nanoparticles for use in liquid crystal Nano-colloids now relies mostly on mechanical grinding of ferroelectric materials. The surfactant and ferroelectric material are blended in a dielectric fluid carrier. The size of the created nanoparticles and the distribution of their sizes are determined by the milling period, which is heavily impacted by the material choice and milling machine design."

II. REVIEW OF RELATED STUDIES

Singh, Bhupendra et al., (2022)"We conduct an in-depth analysis of the issue by looking at the dielectric, electro-optical, and optical properties of a dilute suspension of ferroelectric barium titanate nanoparticles (BaTiO3 NPs) in a nematic matrix. In BaTiO3, a strong surface electric field (on the order of 1010 Vm1) induces the formation of pseudonematic domains inside the matrix, which in turn results in an increase in the perpendicular and parallel components of the dielectric permittivity as the concentration of NPs rises. The dielectric anisotropy of pure nematic material rises by 10.7%, 24.6%, and 33.3% with addition of 0.1, 0.3, and 0.5 wt, respectively, due to shifts in molecular ordering. percent BaTiO3 NPs leading to a drop in threshold voltage. Electro-optical response times for cells made with a nematic-BaTiO3 mix were 23, 49, and 67 percent quicker at 0.1, 0.3, and 0.5 wt, respectively. different percentages of NPs BaTiO3 NPs behave as chromophores in the nematic matrix, increasing the degree of conjugation and causing a bathochromic shift in the fluorescence spectra. Based on the results of this study, electro-optical devices using ferroelectric BaTiO3 NPs-nematic composites should provide excellent performance."

Nasri, Rawia et al., (2021) "Impedance and dielectric spectroscopic measurements were performed in the frequency range of 1 Hz-2 MHz to characterise the electrical and dielectric characteristics of a ferroelectric nanoparticle-doped liquid crystal cell. We present an appropriate impact equivalent electric circuit and use impedance spectroscopy to determine its characteristics. The effect of the nano-particles on these parameters is shown and explained; this effect is ascribed to the accumulation of mobile charge carriers close to the electrodes of the cell. Dielectric anisotropy () is shown to be enhanced by the presence of nanoparticles, whereas loss tangent is kept to a minimum. Consequently, we get a very high = 120 at low frequencies (below 100 Hz) and a very low = 27 at high frequencies (above 100 Hz). The dielectric measurements demonstrate that the interfacial polarisation, a minor increase in the diffusion coefficient, and the ion mobility all contribute to the emergence of low-frequency relaxation (f 500 Hz) in the presence of the nanoparticles. The results of this study provide the groundwork for future quantitative studies of the interface effect in dielectric composites."

Katiyar, Rohit et al., (2020) This research uses electro-optical and dielectric spectroscopy to analyse a nematic liquid crystal (NLC) made of 4′-(Octyloxy)-4-biphenylcarbonitrile that has

been disseminated with three different quantities of silver nanoparticles (Ag NPs). Physical properties such dielectric permittivity, photoluminescence, threshold voltage, reaction time, and splay elastic constant are affected by the incorporation of Ag NPs into NLC material. Ag NPs distributed in a composite system have led to notable improvements in that system's AC conductivity and threshold voltage. The composite system's improved AC conductivity may be traced back to an induced charge transfer process that is aided by the presence of Ag NPs. The relevance of the Ag NPs/NLC composite system in photovoltaic solar cells is further shown by the fact that its AC conductivity value increases.

Agrahari, Kaushlendra et al., (2019) In this study, we want to show how tin oxide (SnO2) nanoparticles alter the morphology, dielectric properties, thermal stability, and optical properties of multicomponent ferroelectric liquid crystals (FLC). The various FLC physical features and their relation to dopant concentration have been discussed. Self-assembled two-dimensional arrays of nanoparticles have been seen forming in the planar aligned patterns of composites that are perpendicular to the direction of rubbing. Differential scanning calorimetry data lends credence to the idea that the composites' phase transition temperatures have shifted. The addition of nanoparticles has resulted in a reduction in relative permittivity, absorption strength, and ac conductivity. Optical extinction was decreased in the pure ferroelectric liquid crystal upon incorporation of tin oxide nanoparticles. The quenching behaviour was seen in a ferroelectric liquid crystal that included dispersed nanoparticles.

Singh, Upendra. (2018) As a result, we have created composites of gold nanoparticles and 4-(trans-4′-n-hexylcyclohexyl) isothiocyanatobenzoate (6CHBT), a nematic liquid crystalline material that is stable at normal temperature (GNPs). Research has been done on the thermodynamic, electro-optical, and dielectric characteristics. Research has been done on how dispersing GNPs affects the electro-optical and display properties of the host liquid crystalline material. For composite systems, the values for physical factors such as threshold voltage, dielectric anisotropy, and splay elastic constant have changed. Spreading GNPs causes the transition temperature from nematic to isotropic phases to rise dramatically. The addition of GNPs has led to an increase in the relaxation frequency that corresponds to the flip-flop motion of the 6CHBT molecules around their short axes.

Praveen. (2017) We have looked at what happens when nickel nanoparticles (NiNPs) are added to a batch of 100% ferroelectric liquid crystal (FLC). The frequency range of the dielectric spectroscopy was 20 Hz to 10 MHz. Through the use of the field reversal approach, we have determined the switching time, spontaneous polarisation, and rotational viscosity of the SmC phase. An increase in spontaneous polarisation is seen for the NiNPs-FLC sample, which may be attributable to induced dipole moments surrounding FLC molecules. It has been shown that the reaction time lowers as the temperature and the dispersion of the NiNPs increase. Pure FLC and NiNPs-FLC samples are compared and contrasted with regards to relaxation frequency and dielectric strength of observed mode in SmC phase. The NiNPs-FLC sample was found to have a relaxation frequency of 120 Hz, which is lower than that of the pure FLC sample.

Garbovskiy, Yuriy & Glushchenko, Anatoliy (2017)"Dispersing ferroelectric nanoparticles in liquid crystals has emerged as a viable way for developing advanced and malleable electro-optical materials in recent years. The primary goal of this article is to offer a comprehensive overview of the state of the art, the underlying physical principles, and the real-world applications of ferroelectric nanoparticle/liquid crystal colloids." Finding solutions to the scientific and technical challenges in the rapidly developing area of liquid crystal Nano science requires aggregating and interpreting a large amount of experimental data in the context of preexisting theoretical models. The production of a stable and aggregate-free dispersion of relatively small (10 nm) ferroelectric nanoparticles in liquid crystals; (ii) the selection of liquid crystal materials most suitable for the dispersion of nanoparticles; (iii) the control of the size, shape, and Ferro electricity of nanoparticles; (iv) the selection of suitable experimental techniques and control measurements to characterise liquid crystals.

Khushboo et al., (2017) This research looks at the effects of incorporating ferromagnetic nickel nanoparticles (NiNPs) of sizes between 20 and 40 nm into a ferroelectric liquid crystal (FLC) solution. Size-dependent effects on the electro-optic, dielectric, and optical characteristics of the FLC mixture have been investigated and described. NiNPs-FLC samples exhibit somewhat better spontaneous polarisation, rotational viscosity, and quicker reaction time compared to pure FLC. All samples exhibit the same Debye-type relaxation behaviour at the Goldstone mode frequency of 100 Hz. It is also shown that the relaxation frequency and dielectric strength of NiNPs are not

significantly affected by their size. When analysing both pure FLC and NiNPs-FLC samples, a single absorption peak is seen at 363, 362 Hz.

Lin, Yaochen et al., (2017) Doping the 4-n-octyl-4′-cyanobiphenyl liquid crystal with ferroelectric nanoparticles made of harvested and unharvested tin thiohypodiphosphate (Sn2P2S6) (8CB). Increases in phase transition temperatures show that the collected nanoparticles have a higher order parameter because of their stronger interactions with the molecules of the liquid crystal. Dialectric characterisation findings corroborate this. When the order parameter is raised, the dielectric permittivity is raised in the homeotropic direction. An increase in the dielectric permittivity is caused by a minor reorientation of the liquid crystal direction from its original planar orientation due to the link between the spontaneous polarisation of the nanoparticles and the order parameter in the planar orientation. Specifically, this impact matters more for liquid crystals that have been infused with collected nanoparticles.

Shukla, Ravi et al., (2016) Very high spontaneous polarisation Ferroelectric Liquid Crystals (FLCs) were produced by dispersing harvested ferroelectric nanoparticles of BaTiO3 and LiNbO3 (Ps). Both the dielectric and electro-optical properties were recorded. When placed in an antiparallel configuration, the dipoles of ferroelectric nanoparticles and FLCs largely cancel one another out. For both single high-Ps FLCs and high-Ps FLC/BaTiO3 Nano colloids, the authors explain the impact of cell characteristics such as Nylon 6 polymer layer thickness and the modification of polymer layer preparation owing to various mechanical rubbing cycles. The dipoles of ferroelectric nanoparticles and high-Ps FLCs may interact with anchoring forces, which have a major impact on cell characteristics.

Lahiri, Tanmoy et al., (2013) "A hypothesis for the statistical mechanics of nanoparticles doped in ferroelectric liquid crystals was established by us (FLC). The presence of nanoparticles in FLC medium generates strong local fields that significantly affect the nano-suspension dispersal. With these local field effects in mind, we created a modified Landau free energy to calculate the system's electro-optic properties. Finally, we investigated the response of the FLC doped with nanoparticles to an external electric field. Changes in polarisation and tilt angle may be shown to be significantly different from the pure FLC medium. The rotational viscosity of the system is also calculated, along with the effects of temperature and external field. We then conjectured that an electrostatic interaction between the nanoparticles and the liquid crystal molecules would

cause a shift in the transition temperature. Finally, we provide convincing experimental evidence that corroborate our conclusions based on this theoretical model."

Neeraj & Raina, K.. (2013) As research into nanoparticles-liquid crystal composites progressed, it became more intriguing to quantify the different physical properties, ideally close to the transition temperature. Chemical reduction of a nickel hydrazine complex in an aqueous solution at 60 °C yielded nickel nanoparticles with a size distribution of 2-8 nm. Increased transmittance and a quick switching response were seen when nickel nanoparticles were placed in a new ferroelectric liquid crystal mixture at a concentration of just 0.5 weight percent. The inclusion of nickel also shows a modest enhancement in the ferroelectric sample's conductivity. This research shows that metallic nanoparticles and ferroelectric liquid crystal molecules interact strongly through dipole forces when an electric field is introduced.

Blach, Jeanet al., (2010) In this research, we provide results from experiments with a composite of BaTiO sub>3/sub> ferroelectric nanoparticles and nematic liquid crystal (5CB) (NPs). We focused on the properties of those NPs rather than the stated significant change in the electro-optical (EO) capabilities of this combination. First, the powder formed by the solid method is investigated; x-ray diffraction and Raman spectroscopy demonstrate that this material crystallises in the ferroelectric phase. The NPs were obtained by a high-speed second milling process, and their size, shape, and other properties have been studied using high-resolution transmission electron microscopy and dynamic light scattering. Then, a nematic liquid crystal was mixed in with the NPs (5CB). The scalar order parameter was determined by Raman spectroscopy and compared between the two samples. Using a standard EO setup, the EO characteristics of a planar liquid crystal cell were determined. Surprisingly, we observed a substantial drop in the Freedericksz threshold compared to the pure material. This is in contrast to a comparable concentration combination of smaller NPs measured by Glushchenko, who found no fluctuation. Using the same apparatus, we found that the " sub> on /sub> " for the 5 CB + BTO combination was shorter than that for pure 5CB during the switching tests.

Haase, Wolfgang et al., (2011) Significant reductions in key characteristics including spontaneous polarisation and switching time but no change in the tilt angle are seen in nanocomposites made from a self-prepared Ferroelectric Liquid Crystalline (FLC) matrix and several nanomaterials. Silver nanoparticles were studied as a representative sample. When the

parameters of FLC Nano composites were compared to those of the pure FLC mixture, a significant increase in resistivity was observed. The possibility of ion capture by silver particles has been considered. It has been documented how the Silver Surface Plasmon Resonance may boost photoluminescence that is generated by a terphenyl molecule.

Kralj, Samo et al., (2008) Here we investigate how nanoparticles (NPs) affect the ordering of liquid crystals (LCs). Regarding the structural ordering, we think of NPs as a source of a quenched random field. Mixed LCs and aerosil NPs roughly present this condition (aerosil NPs are spherular ones). We demonstrate the formation of a quasi-stable domain pattern after a quench from the isotropic phase using the semi-microscopic lattice model and Brownian molecular simulation. Average domain sizes tend to increase as NP concentrations decrease, and there is a memory effect seen in domain patterns. To better understand the phase behaviour, we focus on NPs that are structurally similar to LC molecules. The Maier-Saupe molecular method is used to construct a Landau-type free energy equation for the combination. We demonstrate that when the temperature or pressure is changed, the ensuing phase behaviour displays the slave-master behaviour.

Li, Fenghua et al., (2006) The use of naturally occurring low quantities of ferroelectric nanoparticles to alter liquid crystals (LCs) is described. The stability and resemblance to pure LC of these diluted colloids is impressive. Physical features of LC materials, such as nematic isotropic transition temperature (TNI), dielectric constants, birefringence (n), elastic constants, and threshold voltage, may be controlled by varying the concentration and kind of ferroelectric particles. Doping an LC MLC-6609 with a small amount of BaTiO3 nanoparticles (1%) improves its TNI to temperatures as low as 40°C. We conclude that the LC and ferroelectric nanoparticles interact strongly on a molecular level because of this unprecedentedly large change in TNI. Additionally, the birefringence (10-30%), dielectric anisotropy (50%), and elastic constant K33 (20%) of the doped LC are all significantly improved. As molecular additions, ferroparticles alter the inherent characteristics of LC materials with little to no costly and time-consuming chemistry. Displays, switchable lenses, beam steering, and other light-control devices may all benefit from the new LC materials.

Gap in the Research Work

Research gap is a research question or problem which has not been answered appropriately or at all in a given field of study. Research gap is actually which makes your research publications because it shows that you are not just duplicating the existing research work. It indicates, you havea deep understanding and knowledge in selected research area. Identifying the gaps and generating the research questions can be regarded as the first and most important step in writing a research paper. There are many approaches for overcoming this difficulty, but finding original and innovative topics and distinguishing gaps in the literature is never an easy feat.

Every in the world hundreds of journals on soft materials like liquid Crystals and Polymer papers are published but there is gap in the published works, so there is no end of this work. If we do some new things, it further expand the gap.

Objects

1. To Study the optical parameters of Nano-dispersed Nematic and erroelectricliquid crystal mixtures.
2. To study electrical properties of Nano-dispersed Nematic and Ferroelectric Crystal.
3. To study of thermal parameters of Nano-dispersed Nematic and Ferroelectric Crystal.
4. To identify the texture of Nano-dispersedNematic and Ferroelectric Crystal.

III. SIGNIFICANCE OF THE STUDY

When it comes to nanoscale materials, NPs are a major player. Due to the alteration and enhancement of host LC materials' features brought about by the dispersion of NPs in LCs, dispersed liquid crystalline systems are now suitable for LCs-based devices. In addition, the dispersion of NPs in LCs often does not cause any noticeable structural deformation in the host LC phases. The dispersed system is often referred to as LC-NPs composites. The incorporation of nanoparticles into liquid crystals has proven to be a very productive concept, leading to a broad variety of fascinating phenomena and new, multifunctional materials. The effect of magnetic nanoparticle dispersion on the physical features of nematic and ferroelectric liquid crystal composites was extensively investigated in a planar cell.

IV. PROPOSED METHODOLOGY

5.1 MATERIALS USED

The present study will use ferroelectric liquid crystals (FLCs) sold under the brand names ZLI 4851-000 and W206 E. Also, nematic liquid crystal will be available from Sigma Aldrich in India (6OCB). The cyano (CN) group contributes significantly to the 6OCB molecules' longitudinal dipole moment. Nanoparticles of dispersed iron, nickel ferrite, and nickel magnets will be used as dopants. The iron and nickel nanoparticles will be supplied by Sigma Aldrich in India. Instead, we'll make nickel ferrite nanoparticles in the lab. Nickel nanoparticles of 20 nm and 40 nm sizes will also be employed.

5.2 PREPARATION OF LIQUID CRYSTAL CELLS

High transparency (> 85-90%) indium tin oxide (ITO) coated glass substrates with a sheet resistance of 30-60 / will be used to fabricate liquid crystal sample cells in this study. After being cleaned in soapy water, the substrates will be rinsed in 99.9% pure acetone, distilled water, and dried in a vacuum chamber. Once the ITO substrates have been cleaned, they will be placed in a laminar flow chamber for further sterilisation. Homoetropic LC alignment is not chosen, but homoeotropic alignment is.

5.3 PREPARATION OF MAGNETIC NANOPARTICLES DISPERSED LIQUID CRYSTAL SAMPLES

Small quantities of magnetic nanoparticles (MNPs) will be added to liquid crystal mixtures at varying concentrations to produce magnetic nanoparticles (MNPs) scattered liquid crystal samples. First, MNPs will be ultrasonified at a frequency of 36 kHz for an hour after receiving 1-2 drops of a surfactant (chloroform or oleic acid). The problem of MNPs being too exaggerated will be avoided by using surfactant.

5.4 INSTRUMENTS DETAILS AND EXPERIMENTAL TECHNIQUES

Following experimental techniques will be used for this study: -

- Polarizing optical microscopy

- Temperature programmer cum heating/freezing stage
- Transmission electron microscopy (TEM)
- Vibrating sample magnetometer (VSM)
- Differential scanning calorimetry (DSC) measurements

Polarization switching studies:

The current reversal method is among the most exact techniques for determining a variety of electro-optic characteristics. Both reaction time and spontaneous polarisation will serve as major metrics.

V. EXPECTED OUTCOME

This thesis will discuss how to make liquid crystal composites with magnetic nanoparticles scattered throughout, how to understand them, and how to systematically investigate them. The manufactured materials will be characterised by means of electro-optical, thermal, and dielectric spectroscopy, in addition to polarising and thermal microscopy.

It will be determined that the incorporation of magnetic nanoparticles into liquid crystals enhances their physical properties. Based on the enhanced LC properties, a soft magneto-electric material that can tune with magnetic and electric fields may be produced using a combination of magnetic nanoparticles and liquid crystals. Our next step will be to explore and study soft magneto-electric materials for magneto-optical applications. The more we learn about these systems and the connection between magnetic nanoparticles and soft materials, the more motivated we will be to develop such materials for use in rapid response display displays.

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